Lesson 7

Use of Meteorology in Air Quality Regulatory Programs

Goal

To familiarize you with how meteorology is used in air quality regulatory programs.

Objectives

Upon completing this lesson, you should be able to do the following:

1. Explain how meteorology is used in New Source Review.

2. Identify four broad categories of data that should be considered when selecting an air quality model for a particular source.

3. Explain the importance of representativeness of meteorological data in air quality modeling and give some examples where a data set may not be valid for the situation being modeled.

4. Describe how wet deposition is used in regulatory applications.

5. Name two possible hazards associated with the emission of water vapor plumes.

6. Explain the importance of meteorology in emergency planning and response.

Introduction

The Clean Air Act Amendments require that State Implementation Plans be developed, the impact upon the atmosphere be evaluated for new sources, and air quality modeling analyses be performed. These regulatory programs require knowledge of the air quality in the region around a source, air quality modeling procedures, and the fate and transport of pollutants in the atmosphere. Implicit in air pollution programs is a knowledge of the climatology of the area in question.

The following sections describe the role meteorology plays in sources complying with regulatory programs and air quality standards.

State Implementation Plans

State Implementation Plans (SIPs) are federally approved plans developed by state (or local) air quality management authorities to attain and maintain the national ambient air quality standards (NAAQS). Generally, these SIPs are a state's (local) air quality rules and regulations which are considered an acceptable control strategy once approved by the Environmental Protection Agency (EPA). The purpose of SIPs is to control the amount and types of pollution for any given area or region of the United States.

In these types of control strategies, emission limits should be based on ambient pollutant concentration estimates for the averaging time that results in the most stringent control requirements. In all cases these concentration estimates are assumed to be the sum of the pollutant concentrations contributed by the source and an appropriate background concentration. An air quality model is used to determine which averaging time (e.g. annual, 24-hour, 8-hour, 3-hour, 1-hour) results in the highest ambient impact. For example, if the annual average air quality standard is approached by a greater degree (percentage) than standards for other averaging times, the annual average is considered the restrictive standard. In this case, the sum of the highest estimated annual average concentration and the annual average background concentration provides the concentration which should be used to specify emission limits. However, if a short-term standard is approached by a greater degree and is thus identified as the restrictive standard, other considerations are required because the frequency of occurrence must also be taken into account.

New Source Review

New major stationary sources or major modifications to existing sources of air pollution are required by the Clean Air Act to obtain an air quality permit before construction is started. This process is called New Source Review (NSR), and it is required for any new major stationary source or major modification to an existing source regardless of whether or not the National Ambient Air Quality Standards (NAAQS) are exceeded. Sources located in areas which exceed the NAAQS (nonattainment areas) would undergo nonattainment New Source Review. New Source Review for major sources in areas where the NAAQS are not violated (attainment areas) would involve the preparation of a Prevention of Significant Deterioration (PSD) permit. Some sources will have the potential to emit pollutants for which their area is in attainment (or unclassifiable) as well as the potential to emit pollutants for which their area is nonattainment. When this is the case, the source's permit will contain terms and conditions to meet both the PSD and nonattainment area major NSR requirements because these requirements are pollutant specific.

In most cases, any new source must obtain a nonattainment NSR permit if it will emit, or has the potential to emit, 100 tons per year or more of any regulated NSR pollutant for which that area is in nonattainment. However, the Clean Air Act has established five categories of nonattainment, from "marginal" to "extreme." In areas where air quality problems are more severe, EPA has established lower thresholds for three criteria

pollutants: ozone (VOCs),[1] particulate matter (PM$_{10}$), and carbon monoxide. The "significance levels" are lower for modifications to existing sources.

In general, a new source located in an attainment or unclassifiable area must get a PSD permit if it will emit, or has the potential to emit, 250 tons per year (tpy) or more of any criteria or NSR regulated pollutant. If the source is on EPA's list of 28 PSD source categories, a PSD permit is required if it will or may emit 100 tpy or more of any NSR regulated pollutant. The "significance levels" are lower for modifications to existing sources. In addition, PSD review would be triggered, with respect to a particular pollutant, if a new source or major modification is constructed within 10 kilometers of a Class I area (see below) and would have an impact on such area equal to or greater than 1mg/m^3, (24 hour average) for the pollutant, even though the emissions of such pollutant would not otherwise be considered "significant".

Some new sources or modifications to sources that are in attainment areas may be required to perform an air quality modeling analysis. This **air quality impact analysis** should determine if the source will cause a violation of the NAAQS or cause air quality deterioration that is greater than the available PSD increments. PSD requirements provide an area classification system based on land use for areas within the United States. These three areas are Class I, Class II, and Class III, and each class has an established set of increments that cannot be exceeded. Class I areas consist of national parks and wilderness areas that are only allowed a small amount of air quality deterioration. Due to the pristine nature of these areas, the most stringent limits on air pollution are enforced in the Class I areas. Class II areas consist of normal, well-managed industrial development. Moderate levels of air quality deterioration are permitted in these regions. Class III areas allow the largest amount of air quality deterioration to occur. When a PSD analysis is performed, the PSD increments set forth a maximum allowable increase in pollutant concentrations, which limit the allowable amount of air quality deterioration in an area. This in turn limits the amount of pollution that enters the atmosphere for a given region. In order to determine if a source of SO$_2$, for example, will cause an air quality violation, the air quality analysis uses the highest estimated concentration for annual averaging periods, and the highest, second highest estimated concentration for averaging periods of 24 hours or less. The new NAAQS for PM and Ozone contain specific procedures for determining modeled air quality violations.

For reviews of new or modified sources, the air quality impact analysis should generally be limited to the area where the source's impact is "significant", as defined by regulations. In addition, due to the uncertainties in making concentration estimates for large downwind distances, the air quality impact analysis should generally be limited to a downwind distance of 50 km, unless adverse impacts in a Class 1 area may occur at greater distances.

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[1] Ozone is not emitted by industrial sources; it is formed by volatile organic compounds (VOCs) and nitrogen oxides (known as "ozone precursors") in the presence of heat and sunlight. VOCs emissions are regulated as a surrogate for ozone.

Air Quality Modeling

As mentioned in the previous two sections, air quality modeling is necessary to ensure that a source is in compliance with the SIP and New Source Review requirements. When air quality modeling is required, the selection of a model is dependent on the source characteristics, pollutants emitted, terrain, and meteorological parameters. The EPA has compiled the *Guideline on Air Quality Modeling,* (40 CFR 51 Appendix W) which summarizes the available models, techniques, and guidance in conducting air quality modeling analyses used in regulatory programs. This document was written to promote consistency among modelers so that all air quality modeling activities would be based on the same procedures and recommendations.

When air quality modeling is required, the specific model used (from a simple screening tool to a refined analysis) will need meteorological data. The data can vary from a few factors such as average wind speed and Pasquill-Gifford stability categories to a mathematical representation of turbulence. Whatever model is chosen to estimate air quality, the meteorological data must match the quality of the model used. For example, average wind speed used in a simple screening model will not be sufficient for a complex refined model. An air quality modeling analysis incorporates the evaluation of terrain, building dimensions, ambient monitoring data, relevant emissions from nearby sources, and the aforementioned meteorological data.

For a dispersion model to provide useful and valid results, the meteorological data used in the model must be representative of the transport and dispersion characteristics in the vicinity of the source that the model is trying to simulate. The representativeness of the meteorological data is dependent on the following:

- The proximity of the meteorological monitoring site to the area under consideration

- The complexity of the terrain in the area

- The exposure of the meteorological monitoring site

- The period of time during which the data are collected

In addition, the representativeness of the data can be adversely affected by large distances between the source and the receptor of interest. Similarly, valley/mountain, land/water, and urban/rural characteristics affect the accuracy of the meteorological data for the source under consideration.

For control strategy evaluations and New Source Review, the minimum meteorological data required to describe transport and dispersion of air pollutants in the atmosphere are wind direction, wind speed, mixing height and atmospheric stability (or related indicators of atmospheric turbulence and mixing). Due to the question of representativeness of meteorological data, site-specific data are preferable to data collected off-site. Typically one year of on-site data is required. If an off-site database is used (from a nearby airport for example), five years of data are normally required. With five years of data, the model can incorporate most of the possible variations in the meteorological conditions at the site.

Visibility

Visibility is the distance an observer can see along the horizon. The scattering and absorption of light by air pollutants in the atmosphere impairs visibility.

There are generally two types of air pollution which impair visibility. The first type consists of smoke, dust, or gaseous plumes which obscure the sky or horizon and are emitted from a single source or small group of sources. The second type is a widespread area of haze that impairs visibility in every direction over a large area and originates from a multitude of sources. Regardless of the type of air pollution that impairs the visibility at a particular location, any change in the meteorology or source emissions that would increase the pollutant concentration in the atmosphere will result in increased visibility impairment.

PSD Class I areas have the most stringent PSD increments, and therefore, must be protected not only from high pollutant concentrations, but also from the additional problems pollutants in the atmosphere can cause. Under the Clean Air Act, PSD Class I areas must be evaluated for visibility impairment. This may involve a **visibility impairment analysis**. According to EPA regulations, visibility impairment is defined as any humanly perceptible change in visibility (visual range, contrast, or coloration) from natural conditions. Therefore, any location is susceptible to a visibility impairment due to air pollution sources. Since PSD Class I areas (national parks and wilderness areas) are known for their aesthetic quality, any change or alteration in the visibility of the area must be analyzed.

Pollutant Deposition

Pollutant deposition is the process of pollutants being removed from the atmosphere and deposited onto the surface of the earth. Stack plumes contain gases and a small amount of particles that are not removed from the gas stream. When the plume emerges from the stack, these particles are carried with it. Once airborne, the particles begin to settle out and become deposited on the ground and on surface objects. There are basically two ways the particles can be deposited: **dry deposition** (gravitational settling) or **wet deposition** (precipitation scavenging). Depending on the meteorological conditions during the time of pollutant emission, these particles may:

1. Settle out quickly due to their weight and the effect of gravity;

2. Be transported further downwind of the source due to buoyancy and wind conditions; or

3. Be washed out of the atmosphere by precipitation or clouds (wet deposition).

In any case, the deposition of these pollution particles is important to understand and quantify since pollutants deposited upon the ground can impact human health, vegetation, and wildlife.

Pollutant deposition concentrations must be predicted in order to minimize the risk to human health. In order to quantify the amount of pollutant deposition which occurs from stack emissions, air quality models can be used. These models determine

pollutant deposition based on the chemical reactivity and solubility of various gases and by using detailed data on precipitation for the areas in question.

Vapor Plume Induced Icing

Vapor plumes are emitted from cooling towers and stacks and consist mainly of water vapor. Although pollutant concentrations are not a major concern with vapor plumes, other problems arise when vapor plume sources are located close to frequently travelled roads and populated areas. Vapor emitted from a stack is warm and moist. When meteorological conditions are favorable, the moisture in the vapor plume condenses out and settles on cooler objects (e.g. road surfaces). This phenomena is similar to the moisture that collects on the sides of a glass of water on a warm day. If temperatures are at or below freezing when the moisture condenses, road surfaces can freeze rapidly creating hazardous driving conditions. In addition, light winds can cause the plume to remain stagnant creating a form of ground fog that can cause low visibilities as well. Water vapor plumes that lower visibility can create hazards for aircraft, especially during critical phases of flight including landings and takeoffs.

Emergency Planning and Response

Regulatory agencies require sources that have the potential to release hazardous materials into the atmosphere to implement emergency planning and response procedures. These procedures are designed to enable a facility owner to take emergency action for public protection. In addition, emergency planning can enable the facility owner to provide assessments of the emergency situation based on meteorological parameters and the airborne release of the hazardous chemicals. The emergency plans and procedures include specific meteorological measurements that must be evaluated in order to anticipate the transport and dispersion of any hazardous materials that could be emitted during an emergency situation at a site. Therefore, not only is it important to know which hazardous pollutants a facility is capable of releasing, it is just as important to know the meteorological conditions that are prevalent at the site in order to predict how hazardous substances would be handled if accidentally released into the atmosphere. Continuous on-site meteorological data is an important factor in assessing the transport and dispersion of accidental releases. Information on wind speed and direction, atmospheric stability and mixing height is crucial in determining the area potentially impacted by a sudden release and initiating emergency response actions such as evacuations.

Review Exercise

1. True or False? A State Implementation Plan is a federally approved plan developed by states, to attain and maintain ambient air quality standards.

   a. True
   b. False

2. Emission limits should be based on ambient pollutant concentrations that results in the:

   a. Most stringent control requirement

   b. Least stringent control requirement

   c. An average of the most stringent and least stringent control requirements

3. The analysis used to determine whether a source will cause violations of NAAQS or cause deterioration larger than allowable increments is:

   a. Major modification review
   b. Air quality impact analysis
   c. Significant increment analysis
   d. Violation analysis

4. Pristine areas (national parks, wilderness areas, etc.) that are only allowed small amounts of air quality deterioration are referred to as _____ areas.

5. To determine if SO_2 emissions cause a 24-hour air quality violation, which model concentration estimate would be used?

   a. Third highest
   b. Second highest
   c. Highest, second highest
   d. Highest

6. Why are meteorological data necessary when new source review is required?

   a. Because New Source Reviews are conducted by the meteorologist only
   b. To make sure the new source is not located in an area subject to harsh weather
   c. Because air quality modeling under NSR uses meteorological data
   d. None of the above

7. The four meteorological factors necessary for NSR and control strategy evaluations are:

   a. Humidity, wind speed, wind direction, stability
   b. Precipitation, stability, wind speed, wind direction
   c. Solar radiation, stability, mixing, mixing height
   d. Wind speed, wind direction, stability, mixing height

8. For control strategy evaluations and New Source Review, the minimum amount of meteorological data is _____ year(s) for on-site data and _____ year(s) for data collected nearby.

9. Under the Clean Air Act, PSD Class I areas must be evaluated for
_____ impairment.

10. The process by which pollutants fall out or are washed out of the plume is referred to as:
    a. Transformation
    b. Deposition
    c. Dispersion
    d. Diffusion

11. What are the two ways particles from a plume can be deposited on the ground?
    a. Wet deposition and precipitation scavenging
    b. Wet deposition and dry deposition
    c. Dry deposition and gravitational settling
    d. None of the above

12. Name two hazards associated with the emission of a water vapor plume.

    _____

    _____

Review Exercise Answers

1. **a. True**

   A State Implementation Plan is a federally approved plan developed by states, to attain and maintain ambient air quality standards.

2. **a. Most stringent control requirement**

   Emission limits should be based on ambient pollutant concentrations that results in the most stringent control requirement.

3. **b. Air quality impact analysis**

   Air quality impact analysis is used to determine whether a source will cause violations of NAAQS or cause deterioration larger than allowable increments.

4. **Class I**

   Pristine areas (national parks, wilderness areas, etc.) that are only allowed small amounts of air quality deterioration are referred to as Class I areas.

5. **c. Highest, second highest**

   To determine if SO_2 emissions cause a 24-hour air quality violation, the highest, second highest concentration estimate would be used.

6. **c. Because air quality modeling under NSR uses meteorological data**

   Meteorological data are necessary when New Source Review is required because air quality modeling under NSR uses meteorological data.

7. **d. Wind speed, wind direction, stability, mixing height**

   The four meteorological factors necessary for NSR and control strategy evaluations are wind speed, wind direction, stability, and mixing height.

8. **One, five**

   For control strategy evaluations and New Source Review, the minimum amount of meteorological data is one year for on-site data and five years for data collected nearby.

9. **Visibility**

   Under the Clean Air Act, PSD Class I areas must be evaluated for visibility impairment.

10. **b. Deposition**

    The process by which pollutants fall out or are washed out of the plume is referred to as deposition.

11. **b. Wet deposition and dry deposition**

    The two ways particles from a plume can be deposited on the ground are wet deposition and dry deposition.

12. **Icing of roads**
    Poor visibility

    Icing of roads and poor visibility are two hazards associated with the emission of a water vapor plume.